LUNAR SPINEL ANORTHOSITES: UPDATED CONSTRAINTS FROM ENTHALPY.

A. H. Treiman[1], J. Gross[2], M. J. Kulis[3], and A. F. Glazner[4]. [1]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058 treiman@lpi.usra.edu. [2]Department of Earth and Planetary Sciences, Rutgers University, 610 Taylor Rd., Piscataway NJ 08854, jgross@eps.rutgers.edu. [3]Extreme Environments Laboratory, NASA Glenn Research Center, 2100 Brookpark Road Cleveland, OH 44135, michael.j.kulis@nasa.gov. [4]Department of Geological Sciences, University of North Carolina, Campus Box #3315 Chapel Hill, NC 27599, afg@unc.edu.

The mineral spinel, $(Mg,Fe)Al_2O_4$, is a widespread minor constituent of lunar samples and meteorites [1,2]. Recent and ongoing recognition of lunar highland rock with VNIR reflectance signatures of spinel alone (i.e., containing only spinel±anorthite±glass) [3,4] have escalated interest in the origins of lunar spinel-rich rocks, especially that they might represent material from the deep crust or mantle [3]. Based on enthalpy-composition diagrams (ΔH*-X) for 1 bar, we showed [5] that 'VNIR spinel anorthosites' (rock with VNIR signatures of spinel but not olivine or pyroxene), could reasonably form from impact melts of anorthosite plus simplified picrite or peridotite. We expand those preliminary results to compositions that approximate assimilation of anorthosite into primitive lunar magmas.

Methods: In [5], we applied the graphical method of [6]. Here we add computational models that include non-idealities in melt solutions. Rhyolite-MELTS [7] is used for peridotitc and picritic compositions, but fails to reproduce experimental equilibria for spinel and for the plagioclase liquidus surface. FactSage [8] reproduces experimental liquidi and other phase boundadries for spinel- and plagioclase-rich systems adequately. In FactSage, the field of spinel stability is slightly larger than in experiments (or nature), which does not affect general results here.

Results: Anorthite-Forsterite (An-Fo, $CaAl_2Si_2O_8$–Mg_2SiO_4) is the simplest system, relevant to lunar rocks, in which spinel occurs [9]. FactSage's ΔH*-X phase diagram for An-Fo at 1 bar is similar to the graphical result [5], although consideration of melt solution non-ideality gives some obvious differences.

We approach realistic lunar compositions in the system Anorthite-Forsterite-Diopside-Silica±FeO (An-Fo-Di-Sil±Fe) [9,10], by calculating equilibria along joins from An through the Apollo 14B green glass composition to An-free peridotite compositions in Fo-Di-Sil±Fe. This join passes close to hypothesized compositions of Mg-suite parental magmas [11]. These ΔH*-X phase diagrams are similar to those of Fo-An (Fig. 1) with additional fields for pyroxenes. The ranges of spinel stability, and of 'VNIR spinel anorthosite' formation, are little changed.

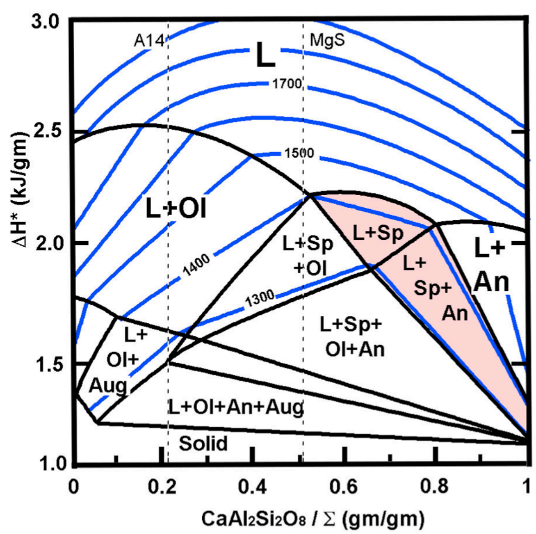

Fig. 1. FactSage ΔH*-X phase diagram for the peridotite-anorthite join in An-Fo-Si-Di-Sil (Fe-free) that includes the projected A14 B green glass composition (A14 dotted line) and a Mg-suite parental magma composition (MgS dotted line). Blue lines are isotherms, in °C. Some complications at low ΔH* are ignored. For any mixture of a melt on the olivine-liquidus and anorthite to fall in a 'VNIR spinel anorthosite' field (pink), the anorthite must have ΔH*>~1.1 kJ/gm, i.e. above ~1300°C. L=melt; Ol=olivine; An=anorthite; Sp=spinel; Aug=augite.

Discussion: The ΔH*-X diagrams show that 'VNIR spinel anorthosite' cannot form at low pressure by simple assimilation of anorthosite into picritic magmas if the anorthosite is cooler than ~1300°C. Such hot anorthosite could arise by: pre-heating from passage of earlier magma, extreme crustal flexing [12], or from asteroid/comet impacts. Given the abundance of lunar impact craters and basins, the last seems most probable.

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